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Ultrashort Pulse Laser

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Ultrashort pulses mean optical pulse duration is at picosecond to femtosecond level, which is the shortest event existing in nature. The ultrashort pulses provide a strobe with which people can "see" the ultrafast events happening in the atoms and molecules. Also, ultrashort optical pulse has a broad equal-spacing comb-shaped spectrum, by which peoples can accurately measure the frequency and time. Currently the optical clock based on optical frequency comb reaches an unprecedented measurement accuracy of 10-17 [1]. On the other hand, "ultrashort" corresponds to "ultrahigh peak power", thus ultrashort pulses find a wide applications in nonlinear optics, material processing, medical imaging and surgery, etc.

Generation of ultrashort optical pulses rely on so called "mode locking" technique, which means the phases of all the longitudinal modes are locked and the laser will generate a strong optical pulse at an instant due to interference of longitudinal modes. Mode locking generally requires a saturable absorber which selects the strong pulses and suppresses the weak pulses in the laser, thus a strong mode-locked pulse is survived finally in the laser.

Since 1990s, semiconductor saturable absorber mirrors (SESAM) have played a dominant role in mode locking [2]. The absorber layer in SESAM consists of quantum wells, thus the bandgap of SESAM can be controllable by engineering the quantum wells. However, SESAMs generally have a limited operation bandwidth and require a complicated fabrication process such as MBE and MOCVD. Currently the SESAMs at 800-2000 nm are matured and reliable, however, SESAMs operating at mid-infrared wavelength are still under-developed.

In 2000s, carbon nanotube was found to enable mode locking as ultrafast saturable absorber [3]. The bandgap of carbon nanotube relies on their diameter and chirality. Thus by selecting the diameter and chirality, carbon nanotube can operate at different wavelengths. However, significant scattering losses due to the bundling and curling of nanotubes may be a problem for low-gain bulk lasers.

In recent years, graphene was found to be an excellent saturable absorber for mode locking [4,5]. Graphene has a zero band-gap and exhibits linear dispersion near Dirac point [6], thus graphene saturable absorbers can operate over an ultrabroad spectral range from visible to far-infrared. Moreover, graphene has the additional advantages of ultrafast recovery time, lower saturation energy fluence, low cost, and easy fabrication, which facilitates its applications. In addition, ultrafast saturable absorbers such as topological insulator and gold nanorod have also been noticed [7,8].

In view of their unique characteristics, ultrashort pulse lasers will play an increasingly important role in material processing, medical treatment and biological technology in the future.

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